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A Buffer Stock Model to Ensure Price Stabilization and Availability of Seasonal Staple Foods under Free Trade Considerations

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Abstract. Price volatility and scarcity have become a great problem in the distribution system of seasonal staple foods produced by the agricultural industry. There is a salient supply disparity during the harvest and planting seasons. This condition could cause disadvantages to stakeholders such as producers, wholesalers, consumers, and government. This paper proposes a buffer stock model under free-trade considerations to substitute quantitative restrictions and tariffs with an indirect market intervention instrument. This instrument was developed using a buffer stock scheme in accordance with a warehouse receipt system (WRS) and a collateral management system. A public service institution for staple food buffer stock (BLUPP) is proposed as the wholesaler's competitor, with as main responsibility to ensure price stabilization and availability of staple food. Multi-criteria decision-making is formulated as a single objective mixed integer non-linear programming (MINLP) model. The results shows that the proposed model can be applied to solve the distribution problem and can give more promising outcomes than its counterpart, direct market intervention.

Keywords: *BLUPP; buffer stock; indirect market intervention; MINLP; price stabilization; staple food availability; warehouse receipt system.*

1 Introduction

Price volatility and scarcity have become a considerable problem in the distribution system of seasonal staple foods produced by the agricultural industry [1-2]. For instance, there are three causes of supply disparity in the distribution of sugar during the harvest and planting seasons in Indonesia. The period of consumption is twelve months, while the period of supply is only six months out of a whole year [3-4]. Total demand is growing along with population growth. Every household consumes approximately 14.6 kg per year, while the estimated quantity of supply can only fulfill around 80% of the total

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demand [4-5]. Sugar from global markets may be cheaper than from the domestic market, because the domestic supply has several weaknesses, such as a low level of sugarcane productivity per hectare, a low level of sugar plant efficiency, and price distortion in the global market [6-7].

The three potential causes of price volatility and scarcity mentioned above, will bring disadvantages and market risks to the stakeholders, *i.e.* producers, wholesalers, consumers and the government [1-2, 4-6]. The producer is forced to sell at a low price in excess-supply periods. Conversely, the consumer has to deal with scarcity and price hikes in excess-demand periods. On the other hand, the wholesaler suffers higher procurement costs during the harvest season and lack of stock during the planting season. Thus, the government cannot really be successful in ensuring food security for people, and welfare for business entities involved in the sugar distribution system.

There are many models for direct market intervention (DMI) to tackle price volatility and scarcity problems. Governments can implement diverse approaches, such as floor/ceiling prices [1-2,4-6,8-9], buffer funds [10-14], export or import taxes [15-17], and subsidies [18-19]. Unfortunately, since countries are involved in the General Agreement on Trade and Tariff (GATT), each country must reduce DMI instruments in accordance with GATT principles to minimize barrier and quantitative restrictions in international trade [20]. This situation forces governments to explore new instruments that conform to the GATT free-market principles (FM). None of the papers cited above provide an appropriate model to address the three main causes of supply disparity in sugar distribution in Indonesia, *i.e.* supply shortage, high price-level, and price distortions in the global market.

This research tries to address the gap that currently exists between the available literature and the real problems in sugar distribution in Indonesia. As for the papers cited above, none of the models they propose is appropriate for solving the real problems while conforming to the principles of GATT. Nur Bahagia [21] presented a buffer stock scheme consisting of program planning, procurement, inventory, and operation.

Buffer stock could be utilized as collateral credit. The warehouse receipt system (WRS) is a proven method for obtaining financial security by keeping goods in a warehouse [22]. In Indonesia, the WRS is backed up by the Warehouse Receipt System Law No. 9, 2006 [23]. The buffer stock scheme, in accordance with a WRS and a collateral management system (CMS), might be able to solve the problems mentioned above. The buffer stock scheme should be modified as an indirect market intervention (IMI) instrument to conform to the GATT principles for intervened markets.

This paper proposes an IMI instrument that aims to relieve the government in ensuring price stabilization and availability of seasonal staple foods. This paper is organized as follows. Section 1 describes the background of the research, including the problems in the real system, and indicates the present research gap. The IMI approach is presented in Section 2. Section 3 contains the mathematical model to solve the IMI. Solution method and analysis are explained in Section 4. And finally, in Section 5, conclusions and future research are discussed.

2 The Indirect Market Intervention Approach

Figure 1 (Subsystem A) describes the distribution system of a seasonal staple food (sugar). There is no damage when the staple food is being stored in warehouses and it cannot be replaced by substitute products. The current distribution system consists of three main structural entities, namely the producer (P), the wholesaler (W), and the consumer (C). During the harvest season, the producer sells the staple food to the wholesaler and the wholesaler sells it to the consumer. Purchasing price and selling price are determined by the basic laws of supply and demand. During the planting season, only the wholesaler sells the staple food to the consumer, and it is often that the wholesaler with excess inventory will speculate the market by increasing the selling price. In the proposed system a new entity, namely BLUPP (a public service institution for staple food buffer stocking), is recommended as a competitor for the wholesaler. The performance of the distribution system is measured by price stability and availability of product.

Figure 1 (Subsystem B) shows the IMI instrument. The staple-food distribution system will be intervened by applying the IMI instrument, whereby the government indirectly influences the market supply-and-demand equilibrium. The BLUPP applies a buffer stock scheme in accordance with a WRS and a CMS as IMI instruments, called the Subsidy for Warehouse Receipt System (S-WRS). There are three institutions involved in implementing the S-WRS, namely registered warehouse management (RWM), banks or financial institutions (BFI), and a registration center for warehouse receipts (RCWR) [23-24]. RWM refers to the management that operates a warehouse as a business entity, which keeps, maintains and supervises staple food stored by its owner, and is authorized to issue warehouse receipts (WR). The warehouse receipt is a document that is proof of staple-food ownership stored in the registered warehouse, issued by RWM management. BFI refers to a commercial bank or a financial company that finances and administers the funding of the S-WRS. RCWR refers to a legal business entity that administers WR and their derivatives.

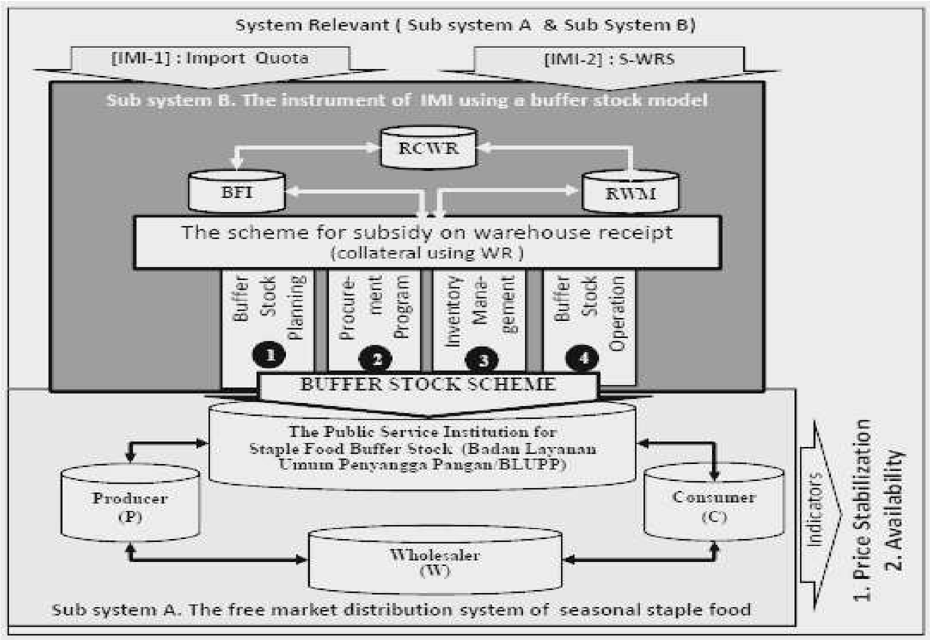

Figure 1 Overview of a seasonal staple food distribution system by using indirect market intervention.

The indirect market intervention approach is summarized in two relevant systems, Subsystem A & Subsystem B. The proposed model assumes that total production is lower than total consumption. Consequently, the BLUPP is permitted to import staple food in accordance with quota to anticipate the market shortage (IMI-1). The BLUPP has the privilege to apply the S-WRS (IMI-2) in order to perform its responsibility. The BLUPP gives WR to BFI for accessing loans. This action will not only lead to an increase of the selling price, but also provide the BLUPP with cash to cover its operational costs. The BLUPP can then obtain back its pawned staple food from RWM, sell it against a profitable selling price, and return its loan to the BFI, along with administration and interest charges. Financial facilities are not given to the BLUPP directly, but to the BFI in the form of an attractive interest rate on the S-WRS in order to reduce quantitative restrictions and tariffs. In this paper, the BLUPP receives a loan from a bank or financial institution in order to perform its responsibility to guarantee availability and to stabilize the price in the consumer market. Interest costs are incurred as an operational cost. An attractive S-WRS determined by the government plays a role as a source of additional income for the BLUPP to perform its activities while assuring profit gain. Hence, it is clear that the S-WRS only affects BLUPP profit directly and the S-WRS rate doesn't influence the price competition in the market directly.

A buffer stock scheme must be able to determine the intervention instrument that is required for the indirect market intervention program as described above. This scheme must consider the expectations of all stakeholders. Both the producer and the consumer should obtain a reasonable price in their transactions with the wholesaler. A reasonable price for the consumer is a price below the maximum price determined by the government under the price stabilization program. Derived from data covering the past 5 years, the maximal buying price for the consumer is 9,600 IDR. Hence, the consumer can expect a reasonable price to be below 9,600 IDR. A reasonable price for the producer is a price that can cover his costs with an additional profit margin. The producer's costs are 7,000 IDR, hence, a reasonable price for the producer must be above 7,000 IDR.

The price must be high enough to cover the seller's costs added by a reasonable profit margin. A non-speculative wholesaler expects that all stock can be sold with a reasonable profit. A reasonable price for the wholesaler is a price that is high enough to cover the seller's costs added by a reasonable profit margin. Therefore, we can assume that a reasonable price for the consumer ≥ reasonable price for the wholesaler ≥ reasonable price for the producer. The BLUPP can execute its responsibility with minimum costs and a reasonable profit. As a result, the government can prevent a staple food crisis and at the same time enhance the welfare of the business actors involved.

3 The Buffer Stock Model Formulation

Before presenting the mathematical formulation, the assumptions and notations are as follows.

3.1 Assumptions

The buffer stock model formulation in this paper is based on the following assumptions. Table 1 lists relevant supply-and-demand market situations along the planning horizon. The length of the planning horizon is 12 months (t_1 to t_{12}) and can be divided into 4 periods: the beginning of the harvest season, the end of the harvest season, the beginning of the planting season, and the end of the planting season. In an indirect market intervention, the market price is determined by the theory of supply and demand, and buffer stocks are organized by the BLUPP. During the harvest season, the BLUPP affects the amount of staple food in the market by determining both the amount of staple food guaranteed as WR and the amount sold directly on the market. Conversely, the BLUPP can manipulate availability during the planting season when they obtain back their pawned staple food from RWM and sell it on the market. This phenomenon represents short-term supply-and-demand problems, which can be solved by implementing IMI instruments (IMI-1) and (IMI-2).

From the data-exploration covering the past 5 years, production and consumption are assumed to be deterministic, because there were little changes in production and consumption, *i.e.* both quantities are relatively stable and can be predicted from year to year. To the best of our knowledge, during the past 5 years no massive policies have been imposed by the government to increase staple production, whether by increasing staple food farms and plants, or by applying innovative production techniques. Hence, the quantity of the staple production can be considered to be deterministic.

Domestic demand is assumed to be proportional to the size of the population, *i.e.* it can be calculated by the multiplication of per capita consumption with the size of the population. Since the population growth number can be acquired from an authorized, reliable source (BPS) and it is commonly small (2-4%), we can assume that the quantity of sugar consumption follows the same growth pattern. The same argument can be used when we look at the production of sugar, *i.e.* the quantity of production can be predicted well. The rationale for sugar production can be applied to sugar consumption, therefore both can be assumed to be deterministic. This model also assumes that the production quantity is smaller than the consumption quantity, as is the case under real conditions in Indonesia.

Table 1 List of market assumptions in a free market.

Periods	p_1 (t_1,t_2,t_3)	p_2 (t_4,t_5,t_6)	p_3 (t_7,t_8,t_9)	p_4 (t_{10},t_{11},t_{12})
1. Season	harvest	harvest	planting	planting
2. Production	normal	booming	none	None
3. Consumption	stable	stable	stable	Stable
4. Availability	sufficient	surplus	sufficient	shortage
5. Price control	------------price support------------		----------price stabilization------------	

3.2 Objective Function

The proposed model has four stakeholders, each having different criteria. The criterion of the producer, the BLUPP and the wholesaler is total benefit, while the consumer's criterion is total cost. The producer expects maximal benefit from his activities. The total benefit for the producer (TB^P) is calculated from the total revenue obtained from selling the staple food during the harvest period, deduced by the total production cost. This can be expressed as:

$$TB^P = \sum_{t=1}^{6} \left(P_t^{p1} - c_p \right) q_t^s \tag{1}$$

The BLUPP's objective is to maximize its benefit (TB^B) as in (2). The first two terms of this objective added together are the total revenue of the BLUPP from selling staple food in the market. Revenues from selling the staple food to the consumer are represented by the first term, whereas income from securing staple food in the registered warehouse (RW) is presented in the second term. The loan-to-value ratio, or credit ratio, is reflected by the relationship between the amount of money the BFI lends and the value of the collateral. The subsequent three terms represent the BLUPP's total costs, which consist of the cost for buying the staple food from the producer, the cost for buying back staple food secured in the RW, and the cost for importing staple food to ensure staple food availability in the market.

$$TB^B = \sum_{t=1}^{12} Y_t P_t^{s1} Q_t^{BC} + \sum_{t=1}^{6} c_r\, Q_t^{WR}\left(P_t^{p1} - c_{wr}\right) - \sum_{t=1}^{6} P_t^{p1} Q_t^{PB} - \sum_{t=1}^{6} c_r\, Q_t^{WR}\left(P_t^{p1} - c_{wr}\right)\left(1 + i_{wr}\right)^6 - \sum_{t=1}^{12} X_t Q_t^{OI}\left(p_i + c_i\right) \qquad (2)$$

Eq. (3) states the wholesaler's objective in his staple-food business activities. The wholesaler's total benefit (TB^W) is calculated from the total revenue for selling the staple food to the consumer, as expressed in the first term of the equation, reduced with the total cost for buying the staple food from the producer, as stated in the second term of the equation.

$$TB^W = \sum_{t=1}^{12} P_t^{s1} Q_t^{WC} - \sum_{t=1}^{6} P_t^{p1} Q_t^{PW} \qquad (3)$$

The last stakeholder in the proposed model is the consumer, whose objective is to minimize total cost for consuming the staple food for whole periods. This objective is expressed in (4). The first term represents the consumer's total cost for buying the staple food during the price-support period, whereas the second term describes the consumer's total cost (TC^C) for buying the staple food during the price-stabilization period.

$$TC^C = \sum_{t=1}^{6}\left(Q_t^{WC} + Q_t^{BC}\right)P_t^{s1} + \sum_{t=6}^{12}\left(Q_t^{WC} + Q_t^{WRR}\right)P_t^{s1} \qquad (4)$$

All of the above objective functions can be formulated as a single-objective mixed integer non-linear programming (MINLP) model. Note that although not explicitly expressed in a symbol, each objective is set to have equal weight (importance). Finally, the objective function is expressed as follows:

$$\text{Max} \quad Z = TB^P + TB^W - TC^C + TB^B \qquad (5)$$

3.3 Constraints Set

Eqs. (6) and (7) are used to determine the producer's selling price and the consumer's buying price under free-market conditions. From (6), it can be inferred that the price will drop when staple-food availability in the market is high. Hence, (8) is introduced as an intervention price in order to protect the producer from price plunges. Conversely, the consumer will face a rise in price when consumption is higher than staple food availability; (9) is utilized to ensure that the consumer will not suffer heavily from price hikes. These two conditions are controlled by using price indicators as expressed in (10) and (11), respectively.

$$P_t^{p0} = p_0^{p0} - c\ln\left(q_t^A\right), t = 1,...,6 \quad (6)$$

$$P_t^{s0} = p_t^{p0} + c_d + \ln\left(q_t^C\right), t = 1,...,12 \quad (7)$$

$$P_t^{p1} = p_t^{p0} - c\ln\left(BIQ_t^W\right), t = 1,...,6 \quad (8)$$

$$P_t^{s1} = P_t^{p1} + c_d + \ln\left(IQ_t^C\right), t = 1,...,12 \quad (9)$$

$$P_t^{p1} \geq CIP, t = 1,...,6 \quad (10)$$

$$P_t^{s1} \leq CIC, t = 1,...,12 \quad (11)$$

Staple-food availability and consumption are used to determine the non-intervention price in (6) and (7). Staple-food availability and consumption are defined in (12) and (13). For the intervened producer's selling price, the initial inventory of staple food is used for every period owned by the wholesaler in (14), whereas the accumulative wholesaler's ownership of the staple food during a certain period in (15) is used to determine the intervened consumer's buying price.

$$q_t^A = q_{t-1}^A + q_t^s, t = 1,...,6 \quad (12)$$

$$q_t^C = q_{t-1}^C + q_t^d, t = 1,...,12 \quad (13)$$

$$BIQ_t^W = BIQ_{t-1}^W + Q_t^{PW} - Q_t^{WC}, t = 1,...,12 \quad (14)$$

$$IQ_t^C = IQ_{t-1}^C + Q_t^{WC}, t = 1,...,12 \quad (15)$$

Eq. (16) states that the amount of available staple food, *i.e.* the staple food produced by the producer, is equal to the amount of staple food purchased by the BLUPP and the wholesaler. The BLUPP will then determine the amount of staple food directly to be sold to the consumer and the amount to be secured in the RW. These expressions are reflected in (17) and (18) respectively. To ensure staple food availability in the market during the harvest season, Eq. (19) is enforced, stating that the BLUPP must sell the amount of staple food directly to the customer to ensure availability in the market, along with the amount of imported staple food and the amount of staple food sold by the wholesaler.

$$Q_t^{PB} = q_t^A - q_{t-1}^A - Q_t^{PW}, t = 1,...,6 \quad (16)$$

$$Q_t^{BC} = \text{Min}\left\{Q_t^{PB}, q_t^d\right\}, t = 1,...,6 \quad (17)$$

$$Q_t^{WR} = Q_t^{PB} - Q_t^{BC}, t = 1,...,6 \quad (18)$$

$$Q_t^{BC} = q_t^d - Q_t^{WC} - X_t Q_t^{OI}, t = 1,...,6 \quad (19)$$

During the price stabilization period, *i.e.* from period 7 to 12, the producer is assumed to no longer supply staple food. Therefore, the BLUPP must redeem its staple food from the S-WRS to sell it on the market or import the necessary amount of staple food. The wholesaler also cannot purchase additional staple food, hence, the amount of staple food sold by the wholesaler during this period only comes from the total amount of staple food purchased during the price-support period minus the amount of staple food that was already sold to the customer during period 1 to 6. These conditions are expressed in (20). Eq. (21) is used to ensure that the total amount of staple food sold to the consumer during period 7 to 12 by the BLUPP equals the total amount of staple food secured in the RW during period 1 to 6. The same mechanism is applied in (21) to ensure that the total amount of staple food sold by the wholesaler in the market is equal to the total amount purchased from the producer in (22).

$$Q_t^{WRR} = q_t^d - Q_t^{WC} - X_t Q_t^{OI}, t = 7,...,12 \quad (20)$$

$$\sum_{t=7}^{12} Q_t^{WRR} = \sum_{t=1}^{6} Q_t^{WR} \quad (21)$$

$$\sum_{t=1}^{12} Q_t^{WC} = \sum_{t=1}^{6} Q_t^{PW} \quad (22)$$

The import of staple food is imposed if staple food consumption is greater than its availability, as expressed in (23). Eq. (24) is to enforce non-negative values for the decision variables.

$$Q_t^{OI} = \max\left\{0, q_t^C - q_t^A\right\}, \forall t \in T = 1,...,12 \quad (23)$$

$$Q_t^{PB}, Q_t^{BC}, P_t^{p1}, P_t^{s1}, Q_t^{WR}, Q_t^{WRR}, Q_t^{PW}, Q_t^{WC}, Q_t^{OI} \geq 0 \quad (24)$$

4 Solution Method and Analysis

In this section, the solution method and numerical examples are presented and analyzed in order to illustrate the capabilities of the proposed model.

4.1 The Solution Method

The characteristics of the objective function and constraint sets of the mixed integer nonlinear programming (MINLP) model constructed above are investigated to obtain an appropriate solution method. The objective function is a concave maximization problem and has a set of constraints in a polyhedron, which means that the model has an optimal solution. Sequential linear programming (SLP) and the branch-and-bound (BB) method are used to find the optimal solution of the MINLP formulation. In this research, the branch and bound (BB) method is used to find the optimal solution in discrete and combinatorial optimization [25]. In this case, a one-integer linear programming problem has to be solved at each stage. All feasible values for integer variables are enumerated while applying SLP, using relaxed values to find the optimal solution. The solution procedure is described in Figure 2.

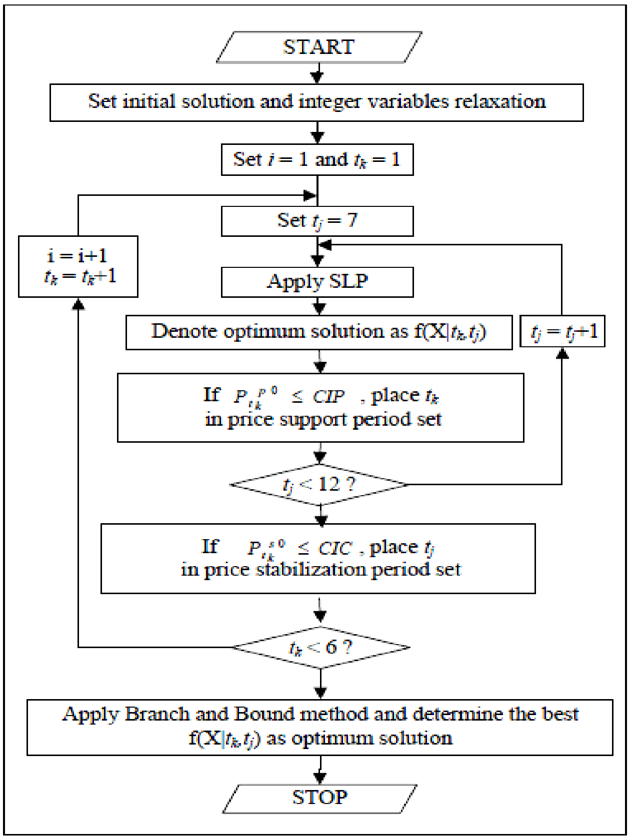

Figure 2 Solution procedure for solving MINLP formulation using sequential linear programming and the branch-and-bound method.

Hereafter, the price-support period is referred to as period 1 to 6, and the price-stabilization period as period 7 to 12. Let t_k and t_j denote the elements of the price-support period set and the price-stabilization period set, respectively. The first iteration step begins with decision variables initialization and binary variables relaxation. Then, the SLP method enumerates all possible values in the price-support period set and the price-stabilization period set. The solution method compares the producer-non-intervention selling price in (6) with (10), and the consumer-non-intervention buying price in (7), with (11) for every iteration step. If the values of t_k and t_j violate (10) and (11), then the solution algorithm assigns the corresponding values in the intervention period set, and the intervention price in (8) and (9) are applied. The last iteration step is to apply the branch-and-bound method for binary variables. This process is repeated until all values in the price-support and price-stabilization sets are enumerated.

In order to verify the solution, we investigate the convexity of the objective functions. All objective functions in (1)-(4) can be classified as linear or non-linear. Linear functions are convex or concave in nature, so no further investigation is needed. For the non-linear objective functions, readers can see that they are all written in terms of $Z = f(X, Y)$, which is a multiplication of two decision variables. It can be found in most optimization studies that such functions are quasi-concave for $X, Y \geq 0$. Putting it all together, we can conclude that all the objective functions are concave, hence the solution is optimal.

4.2 Numerical Examples and Analysis

In this section, numerical examples are used to test the proposed model. The MINLP formulation is solved with the LINGO 9.0 program using a sequential linear programming (SLP) procedure and the branch-and-bound method. Table 2 shows the parameters, price functions, and S-WRS lending interest rate that were used in the numerical examples. The BLUPP receives a loan from the BFI and must pay the loan along with the interest rate, which is called SRG rate. All unit cost and price measurements are in Indonesian domestic rupiahs (IDR). Table 3 shows the supply and demand of the staple food for one planning period, *i.e.* 12 months. Supply-and-demand units are in thousand tons. Supply and demand numbers of the staple food are based on staple food production and consumption in 2010 [26].

Table 2 Parameters, price functions, and S-WRS lending interest rate.

c_p	c_h	c_d	P_{t0}^{p0}	c_i	p_i	*CIP*	*CIC*
7,000	200	400	8,500	300	5,000	7,800	9,600
c	d	i_n	i_{wr}	c_{wr}	c_r		
3	9	0.0117	0.0042	30	0.8		

Table 4 presents the numerical results of the decision variables and their performance criteria for each stakeholder. From the given supply-and-demand data in Table 2 and Table 3, it can be inferred that there is a supply shortage in the staple-food market of about 590 thousand tons for the whole one-year period. In order to satisfy market demand, the BLUPP must import staple food from overseas. Because the import price is lower than the domestic price, the BLUPP gains a more attractive profit by selling imported goods than by selling domestic product from the producer. However, the main objective of importing is to cover domestic shortage, not to gain higher profits. If profit is the main objective, the producer will suffer because the producer's price cannot compete with the import price.

Table 3 Staple-food supply-and-demand data.

Period	1	2	3	4	5	6	7	8	9	10	11	12
q_t^s (x10^3 tons)	240	280	480	630	470							
q_t^d (x10^3 tons)	200	230	230	260	280	280	260	230	240	240	240	210

The total supply of the staple food for the whole one-year period is 2,850 tons. The wholesaler purchased 1,510 tons, while the BLUPP purchased the rest of the staple food supply (1,390 tons). The BLUPP sold the staple food directly to the consumer (540 tons), and secured the rest of it in the RW. During the price-stabilization period, the BLUPP redeemed this staple food in order to fulfill consumer demand during that period. Hence, the total cost for the consumer is decreased up to 30% compared to the system proposed by Sutopo, *et al*. [6]. It is clear that the BLUPP gains more benefit than the wholesaler because of selling imported goods, receiving revenue from selling domestic goods as well as benefits from the S-WRS scheme.

Hereafter the staple-food selling price is referred to as the price that the producer is faced with to sell the staple food for to the BLUPP and the wholesaler, and the staple-food buying price as the price paid by the consumer to buy the staple food from the BLUPP and the wholesaler. The non-intervention selling price and the non-intervention buying price are defined as the prices affected by supply-and-demand theory, as in (6) and (7), and the intervention price as the price intervened by the BLUPP as part of the indirect intervention mechanism to control price stability, as in (8) and (9).

Table 4 Decision variables and their performance criteria for each stakeholder.

Decision variables (DVs)	Quantity or Value of Dvs	Unit
Amount purchased by BLUPP	1.390	thousand tons
Amount imported by BLUPP	590	thousand tons
Amount secured in the RW	800	thousand tons
Amount purchased by wholesaler	1.510	thousand tons
Total benefit for producer	1.162.397, 00	million IDR
Total benefit for wholesaler	912.051,90	million IDR
Total benefit for BLUPP	5.066.810,00	million IDR
Total cost for consumer	19.777.253,00	million IDR

The indirect intervention mechanism of the price support program for producers works as follows: as described in the previous sections, the government gives authority and privileges to the BLUPP, whose responsibility is to ensure staple food price stabilization, while also ensuring producer welfare. The BLUPP's alert system checks the crisis indicator for producer (CIP) to see whether the staple-food selling price lies below CIP and they must intervene, or the selling price lies above CIP and no intervention is required. When the non-intervention selling price lies above CIP due to excessive supply, the BLUPP will buy staple food so that it will decrease until the selling price reaches steady state above CIP.

Figure 3 describes the indirect intervention mechanism during the price-support program period. Note that the non-intervention selling price lies below CIP. Hence, the BLUPP must determine the quantity of staple food bought from the producer, so that the selling price increases and reaches steady state above CIP. In period 1 to 6, when supply excess occurs, the producer suffers potential benefit loss due to a price plunge, causing the selling price to drop below CIP. In order to protect the producer from this potential loss, the BLUPP purchases staple food by using the intervention price, which is higher than CIP, as in (8). As a result, the selling price reaches equilibrium and lies above CIP, while the staple food supply decreases. Moreover, this brings advantage to the producer because by using the intervention price he receives a higher profit than if he would use the non-intervention price.

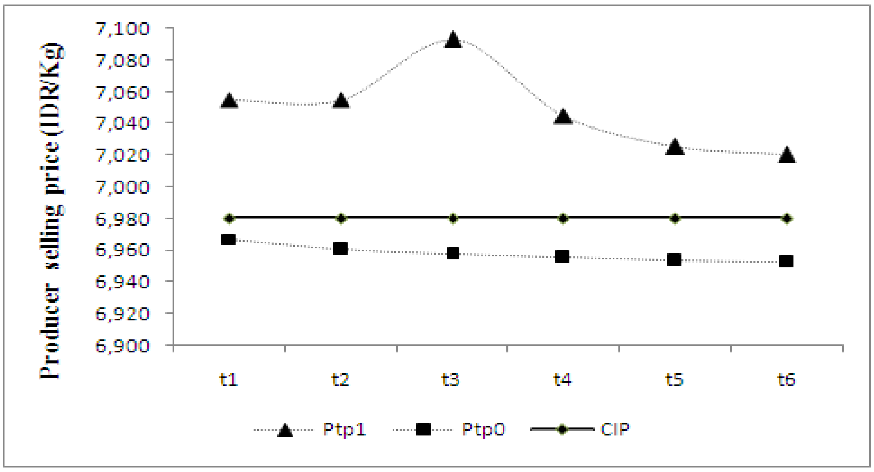

Figure 3 The impact of BLUPP accessing the S-WRS to support the producer-selling price during the harvest season.

The same mechanism is applied for the consumer-price stabilization program. The BLUPP's alert system checks the crisis indicator for consumer (CIC) to control the buying price in the market. Prices above CIC will bring discomfort to the consumer, since the buying price is considered high due to staple food shortage. Therefore, the BLUPP must determine the quantity of staple food to be sold to the consumer aside from the quantity sold by the wholesaler, so that staple food availability and price are maintained. Moreover, this brings advantage to the consumer because the BLUPP's indirect intervention in the market will make the buying price decrease as the staple-food supply increases. As a result, the consumer spends less money to buy the staple food using the intervention price, which is lower than CIC.

The indirect intervention mechanism for the buying price is described in Figure 4. For period 1 to 7, non-intervention buying prices lie below CIC. Therefore, no intervention is required and the consumer buys the staple food by using the non-intervention buying price in (7). However, indirect intervention is required for period 8 until period 12. The staple-food shortage in these periods causes price soaring, hence the BLUPP intervenes in the market by selling its staple food secured in the RW so that the buying price decreases as the supply increases. Hence, the consumer uses the buying price as in (9) during these periods.

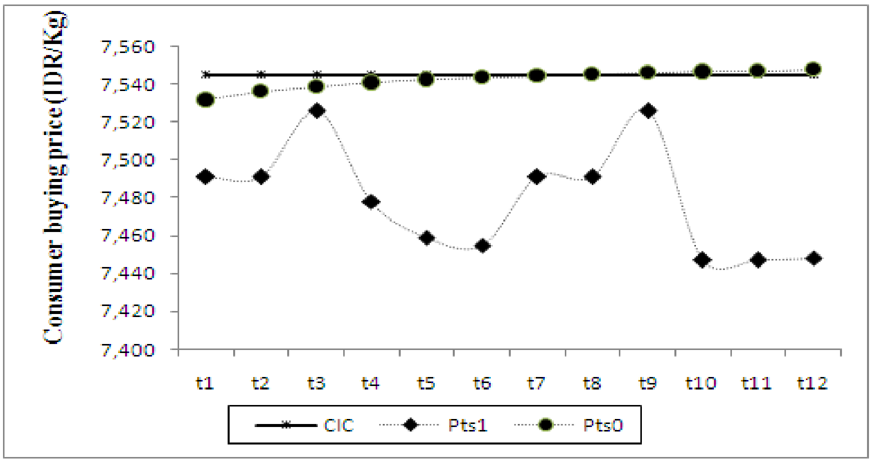

Figure 4 The impact of the BLUPP accessing staple-food secured in the RW to stabilize the consumer buying price during the harvest and planting seasons.

All above numerical results describe the indirect intervention mechanism as part of the BLUPP's responsibilities to ensure staple food availability and price stabilization. Hence, the following propositions are developed based on the mathematical formulations and the numerical results:

Proposition 1 (Price stabilization formulation). *The proposed model can be applied to administer the price-support program for producers and the price-stabilization program for consumers by utilizing a buffer stock scheme under the S-WRS system.*

Proof. The proof is trivial. First, a formal proof for the producer price-support program by selling-price intervention is presented. One can choose arbitrary values for P_t^{p0} less than CIP and P_t^{p1}. Let Φ, Θ, and Ψ denote the value of (1) when the selling price is P_t^{p0}, CIP, and P_t^{p1} respectively. Since (1) is concave, Ψ is always greater than Φ. If intervention is not conducted, the producer will face potential loss to the amount of $\Theta - \Phi$. However, by using the indirect intervention mechanism, the producer will get a benefit to the amount of $\Psi - \Phi$. Next, the same procedure is applied for the price-stabilization program. Let Φ, Θ, and Ψ denote the value of (4) when the buying price is P_t^{s0}, CIC, and P_t^{s1} respectively. Since (4) is monotonous decreasing, Ψ is always smaller than Φ. If intervention is not conducted, the consumer will expedite additional consumption costs to the amount of $\Phi - \Theta$. The BLUPP's indirect intervention will make the consumer reduce his consumption costs to the amount of $\Phi - \Psi$.

Proposition 2 (Staple food availability formulation). *The proposed model can be applied to secure staple food availability throughout the planning horizon by implementing a buffer stock model that considers the expectations of all stakeholders in the staple-food industry.*

Proof. During the harvesting period (season), staple-food availability is greater than consumption. The producer sells staple food to the BLUPP and the wholesaler, and subsequently the BLUPP and the wholesaler sell it to the consumer. Since its availability is greater than its demand, there will be remaining staple food owned by the BLUPP and/or the wholesaler. Equations (16)-(18) reflect this condition. However, during the planting period (season), when the producer cannot provide staple food supply, the remaining staple food owned by the BLUPP and the wholesaler isn't sufficient to cover the consumption. The BLUPP imposes import to overcome this condition. The amount of import must exceed the shortage. This condition is reflected in (20)-(23). Hence, the proposed model can determine the quantity of the staple food sold by the producer, bought by the wholesaler and the BLUPP, and imported by the BLUPP, which satisfies the quantity of staple food consumed by the consumer for the entire planning period.

Proposition 3 (BLUPP responsibility). *The main responsibility of the BLUPP is to ensure staple food availability while expecting to benefit from its market activities.*

Proof. The objective function of the BLUPP in (2) can describe BLUPP activities in the staple-food market. The first term of (2) expresses the BLUPP as staple-food provider. The BLUPP sells staple food along all periods. The BLUPP also gets cash compensation from the S-WRS by staple food pawning; this is expressed in the second term. While undertaking one of its main responsibilities, to ensure staple food availability, the BLUPP expects to gain profit. However, the BLUPP can also suffer profit loss. Let's assume that BLUPP only sells staple food from import, *i.e.* the BLUPP doesn't buy staple food from the producer. Thus, (2) becomes:

$$TB^B = P_t^{s1} Q_t^{OI} - Q_t^{OI}\left(p_i + c_i\right) \tag{25}$$

Notice that (25) can have a negative, zero, or positive value, depending on the staple-food selling price, its price in the global market, and import cost per unit. If the staple-food selling price is higher than the sum of the staple-food price and import cost per unit, (25) will be positive. Conversely, (25) will be negative if the previous conditions are reversed.

To illustrate proposition 3, Eq. (17) is replaced with the following expression:

$$\sum_{t=1}^{6} Q_t^{PB} = \alpha \sum_{t=1}^{6} q_t^s \tag{26}$$

with α ranging from 0 (which means that the BLUPP doesn't get any staple food supply from the producer), up to 100% (which means the BLUPP totally controls the staple food supply).

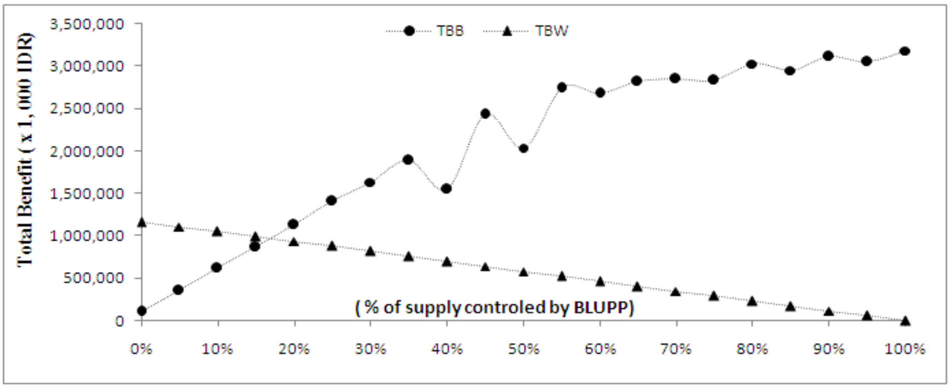

Figure 5 The relationship between staple-food supply control and total benefit.

Figure 5 shows the relationship between staple-food supply and total benefit. The BLUPP still gets revenue from selling imported staple food, even though it has no control over the staple-food supply, whereas the total benefit of the wholesaler is zero when he has no power to control the staple-food supply. The total benefit of the BLUPP and the wholesaler increases as staple-food control increases. However, there is a small difference in the shape of each graphic. The wholesaler's total benefit tends to decrease linearly as the staple food control decreases, whereas the BLUPP's total benefit increases logarithmically as the staple food increases. This can be explained by the fact that the objective function of the BLUPP is not purely linear, while the objective function of the wholesaler is linear.

Table 5 BLUPP benefit.

Staple food controlled by BLUPP (%)	S-SRG lending rate (%)	BLUPP's Profit (Million IDR)
30.00	4.00	686,053.00
40.00	10.00	704,439.00
50.00	12.00	1,043,603.00

A sensitivity analysis was conducted to depict the effect of the amount of staple food controlled by the BLUPP and the S-SRG lending rate on the BLUPP's benefit (Table 5). This means that the BLUPP will get high benefits if the interest rate is low and, conversely, the BLUPP will gain lower benefits if the interest charge is high. This model can provide recommendations related to the staple food controlled by the BLUPP, the rate of S-SRG, as well as the estimation of the BLUPP's profit.

5 Conclusions

A buffer stock model has been developed in accordance with a warehouse receipt system and a collateral management system for solving the scarcity and price fluctuation of a seasonal staple food. S-WRS facilities and direct access to the market are privileges given to the BLUPP in order to perform its responsibility to ensure price stabilization and availability of seasonal staple food under free-trade conditions. The MINLP approach was used to determine the decision variables of the buffer stock scheme as an indirect market intervention instrument. Numerical analysis showed that the model can be used to determine the stock level and the amount of import, and to solve buffer stock problems while considering the interests of all stakeholders.

Further research is needed to extend the model to also consider the dynamic of global market prices, which can influence the domestic price. Other features can be added to make the model more realistic in order to reflect the real system more closely, such as stochastic factors in supply, demand, and prices. Goal programming, stochastic programming, dynamic programming, and robust optimization, to name a few, can be considered as alternative approaches to describe the model extensively. A feasibility study of the BLUPP structure is required to support the government in implementing the proposed model.

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Nomenclature

The following notations are used to develop the proposed model:

BIQ_t^W = the wholesaler's inventory at the beginning of period-t

c = a natural log. parameter of price function

c_d = distribution cost of the wholesaler per unit

c_h = holding cost per unit per year

c_i	=	import cost per unit
c_p	=	production cost per unit
c_r	=	credit ratio by collateral value
c_{wr}	=	administration cost to get the WR
CIC	=	crisis indicator for the consumer of the selling price
CIP	=	crisis indicator for the producer of the purchasing price
i_n	=	normal lending interest rate
i_{wr}	=	S-WRS lending interest rate
IQ_t^C	=	cumulative staple food sold by the wholesaler
p_i	=	staple food price in the global market
P_t^{p0}	=	producer selling price in FM period t
P_t^{p1}	=	purchasing price in IM period t
P_t^{s0}	=	consumer buying price in FM period t
P_t^{s1}	=	selling price in IM period t
q_t^A	=	market's availability in period t
q_t^C	=	amount of consumption in period t
q_t^s	=	supply of staple food in period t
q_t^d	=	demand of staple food in period t
Q_t^{BC}	=	amount of BLUPP and consumer transactions
Q_t^{OI}	=	import quota
Q_t^{PB}	=	amount of producer and BLUPP transactions
Q_t^{PW}	=	amount of producer and wholesaler transactions
Q_t^{WC}	=	amount of wholesaler and consumer transactions
Q_t^{WR}	=	amount of staple food guaranteed in the S-WRS
Q_t^{WRR}	=	amount of buffer stock distributed to the market
X_t	=	BLUPP decision to import staple food $X_t = \begin{cases} 1, \text{ if } q_t^C \geq q_t^A, \forall t \in T = 1,...,12 \\ 0, \text{ otherwise} \end{cases}$
Y_t	=	BLUPP decision to sell staple food to consumer $Y_t = \begin{cases} 1, \text{ if } Q_t^{PB} \neq 0, \forall t \in T = 1,...,6 \\ 0, \text{ otherwise} \end{cases}$

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